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IONOSPHERIC SCINTILLATIONS AT SHF (U)

1976

LUKE K. McSHERRY
UNITED STATES ARMY SATELLITE COMMUNICATIONS AGENCY
FORT MONMOUTH, NEW JERSEY 07703

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SUMMARY: Test were conducted on DSCS Phase II Satellite No. 9433 during quiet solar periods and during solar disturbances. predicted by the Telecommunications Center at Boulder, Colorado on 27 October, 8 November, 21 November, and 10 December 1974.

The major event observed was a variation in the angle-of-arrival of the Beacon Signal from the spacecraft (observed by the only terminal recording angle-of-arrival data) at the same time that all terminals recorded beacon amplitude variations. This seems to indicates that the disturbance that caused the variations in angle-of-arrival and in the signal amplitude were external to the ground terminals, and external to the spacecraft.

The "isolated" nature of this event may lead one to believe that it was a TID - A Traveling Ionospheric Disturbance. A detailed second by second record of its amplitude, may permit further analysis of its character and positive identification.

The possibility that the disturbance originated in the spacecraft directly, causing a perturbation of the beacon signal such that the terminal was driven offtrack for an instant, is considered very remote but is mentioned here for completeness.

INTRODUCTION: In considering the transmission of signals between two or more communication terminals via satellite, ionospheric scintillations present a problem in pulsed systems where information is contained in a coded pulse train and the presence, or absence of a pulse, in a particular train may change the entire context of the message. Such a problem exists in a satellite communication system

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using digital schemes as a modulation method.

No attempt is made here to evaluate the data for a particular application but rather to present information for use as may be required for the system involved. The lack of scintillation data at SHF led to this investigation.

BACKGROUND: Discrete sources of extra-terrestrial noise called radio stars have been studied for years. Soon after beginning the study of radio stars, it was observed that the strength of the signal, as received on earth, fluctuated. This seemed to indicate that the power of the radio source was changing, but it has since been confirmed that the fluctuations were caused by irregularities induced by the change of the electron density in the ionosphere.

The natural electron content of the ionosphere and the artificial belts induced by high altitude nuclear explosion, such as the "Starfish" event, are more or less homogeneous in nature and do not contribute to signal fluctuations as do irregularities caused by solar disturbances. Such irregularities cause scintillations and affect radio signals transmitted between communication satellites and the earth. These scintillations are dependent on geomagnetic activity. In addition, the effects on radio communications are different for different frequencies.

Scintillation fading is an effect observed sporadically on transionospheric propagation paths. It is caused by ionospheric irregularities principally in the equatorial zone and in Auroral zones with little evidence of its occurances at mid-latitudes. Although many measurements of scintillations have been made at UHF frequencies, it was believed in the scientific community that scintillations were non-existent at SHF particularly in the magnetically quiet regions of the earth indicated in Figure #1. However, an accepted model of ionospheric scintillations specifically excludes the SHF region from its range of validity (1). In addition, COMSAT terminals have recorded fades/scintillations at 4-6 GHz in the Equatorial Regions (2), (3). Other investigators have found scintillations at 1.55 GHz.

DISCUSSION: Reports received by the USASATCOMA indicate that random anomalies were being observed on the communications links of DSCS Phase II satellites 9433 and 9434 without a clear explanation of their origin.

The Satellite Communications Agency, in conjunction with the Defense Communications Agency, instituted tests to identify the

REGIONS OF DISTURBED UHF SATELLITE COMMUNICATIONS

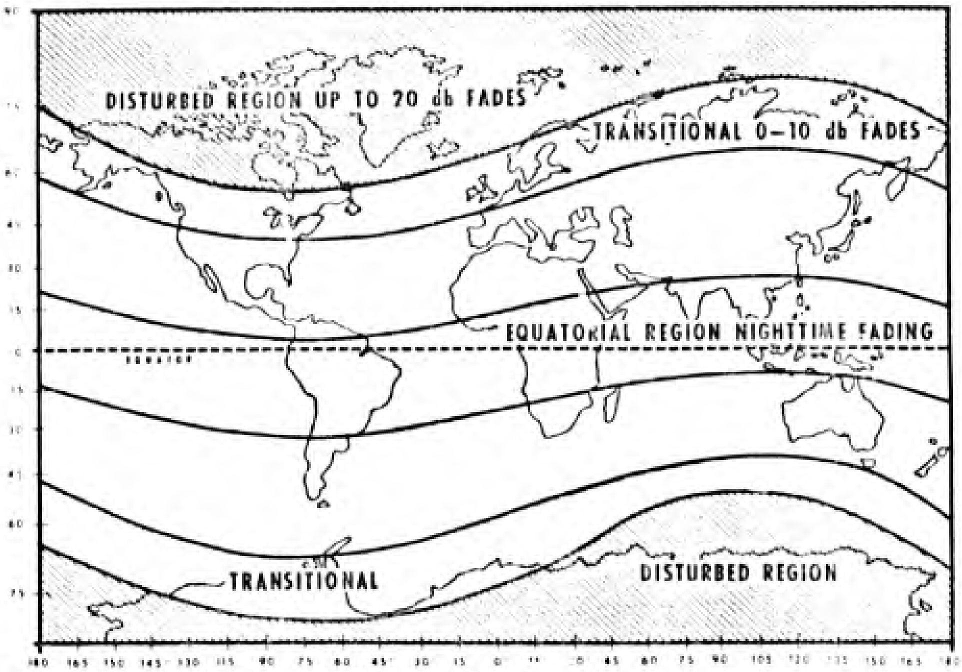

FIGURE 1

SATCOM TEST TERMINAL
EC BEACON
QUIET PERIOD

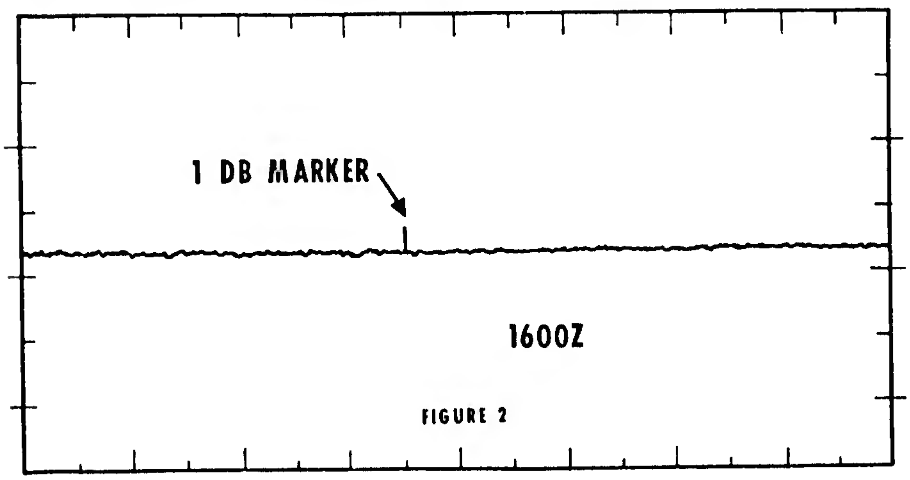

FIGURE 2

GEOGRAPHICAL LOCATIONS AND ELEVATION ANGLES

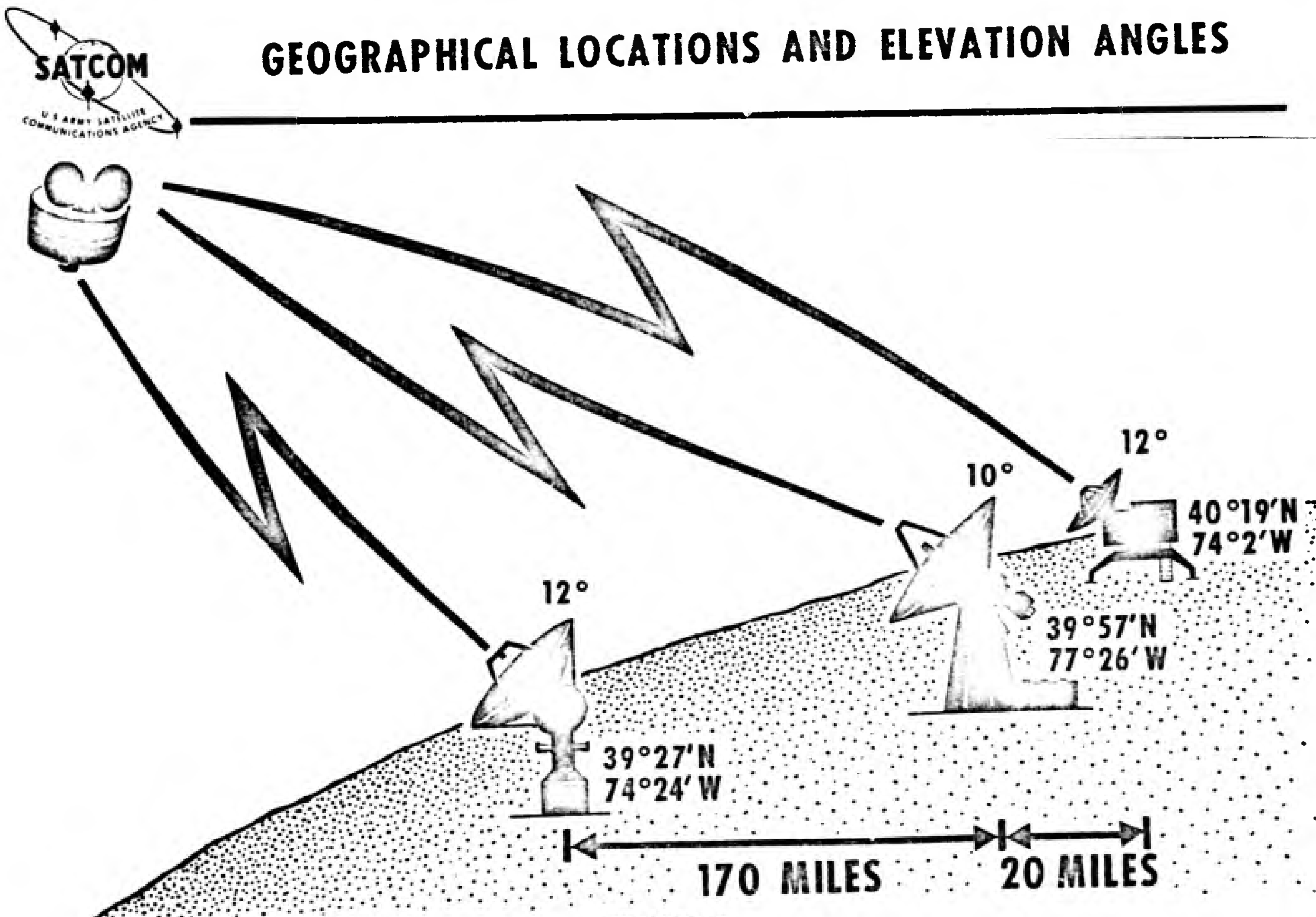

FIGURE 3

anomalies existing on a link over Satellite 9433 which was and positioned over the Atlantic Ocean at the Equator.

A possible explanation previously discounted at 7-8 GHz is now considered. This was that the fluctuations in the received signals were caused by ionospheric scintillations. Tests were conducted on four dates: 17 October, 8 November, 21 November, and 10 December 1974. These dates were selected to coincide with dates of solar disturbances predicted by the Telecommunications Forecast Center at Boulder, Colorado.

Scintillations as related to space communications are defined as amplitude and phase variations of high frequency signals transmitted through the ionosphere from outside the earth. Two common sources are cosmic noise from outer space, and signals from artificial satellites.

The most significant test of the series conducted on 10 December will be discussed here.

TEST CONFIGURATION: In order to obtain a data base, the test terminal at USASATCOMA, monitored the satellite beacon (72'0.1) during a quiet period. It can be seen from the data that the signal varied only 0.5 dB peak-to-peak Figure #2. This is a normal variation due to the atmosphere at the low elevation angle of 12 degrees, interpretation of data from previous tests seem to indicate that the severe disturbances on the signal from the satellite originated as the propagation path passed through the ionosphere. A more detailed test was developed. Three terminal located at mid-latitudes of approximately 40 degrees north were instrumented to record data. The outermost terminals were 190 miles apart, See Figure #3.

The characteristics of these terminals are as follows:

Fort Detrick, MD Lat 39°27'N Long 77°25'W
Antenna Diameter Size: 60 ft.
Antenna Gain (receive) 60 dB
Look Angles EL-12.1°AZ 106.1°

Fort Dix, NJ Lat 39°57'N Long 74°25'W
Antenna Diameter Size: 60 ft.
Antenna Gain (receive) 57.2 dB
Look Angles EL-12°AZ 111°

Fort Monmouth Test Terminal, NJ Lat 40°19°N'Long 74°02'W
Antenna Diameter Size: 15 ft.
Antenna Gain (receive) 48 dB
Look Angles EL-12° AZ 111°

The test configuration for the scintillation test was as follows:

Fort Detrick: A dual channel HP-7100 BM chart recorder was used to monitor and record the elevation and azimuth error voltages to detect angle-of-arrival disturbances. An HP-322A chart recorder was used to monitor and record the beacon signal amplitude from the output of a HP-312A wave analyzer. The Data Acquisition Facility (DAF) was programmed to measure and record the C/kT of the earth coverage beacon at one second intervals.

Fort Dix: An HP-322A chart recorder was used to monitor and record the beacon signal amplitude from the output of a HP-312A wave analyzer.

Fort Monmouth: A PSK signal with a data rate of 19.2 KBPS was generated by an MD-921 (Harris Intertype) modem and transmitted in loop characteristics were such that the received E_B/N_0 (normalized energy per bit to noise density ratio) was 12.2 dB which normally corresponds to an error probability of 10^{-11} an essentially errorless condition. The E_B/N_0 was 7 dB above the threshold margin of 10^{-3} error probability or roughly 20 errors/sec. Data bit errors were recorded on an HP-5850B digital recorder while an HP-322A chart recorder was used to monitor and record the beacon signal amplitude from the output of an HP-312A wave analyzer.

EXPERIMENTAL RESULTS: On 10 December 1974, moderate to severe solar disturbances were predicted by the Telecommunications Forecast Center, Boulder, Colorado.

A test was conducted during the period 0001 hours EST to 0700 hours EST. In order to provide close coordination during the test, the program was directed from Fort Detrick. Hourly reporting was accomplished via autovon. HP-322A recorders were calibrated and started at approximately the same time running at the same chart speed of 5 cm/min. The error voltages indicate a change of angle-of-arrival of the signal, a factor not usually measured in evaluating scintillation phenomena.

Scintillations in angle-of-arrival may be a severe limitation on the performance of SHF systems employing large antenna apertures with their inherent narrow beam widths. If observed events originate in the spacecraft transponder the terminal antenna will track the spacecraft by locking on the strongest signal, and all events generated by the transponder will be recorded. No abrupt variations in antenna error voltage should occur. However, if the events are the result ionospheric disturbances, the signal from the spacecraft is suddently refracted and enters the antenna pattern at a different angle (Figure #4). The tracking receivers will sense a sudden change in signal which will cause an abrupt change in error voltage, tending to shift the antenna to a new angle. This may result in sudden reduction in carrier levels.

During the period from midnight to the onset of ionospheric sunrise on 10 December, a slight variation (0.5 to 1.0 dB peak-to-peak) on the beacon was observed at all terminals. The amplitude of the signals recorded on the charts vary due to different systems gains. However, the times do agree. At approximately 0730Z (0230 EST), severe variation (2 to 5 dB) began to appear on the beacon signal chart recorders at all three terminals (Figure #5). The terminal at USASATCOMA reported a sharp rise in errors of the PSK signal (Figure #6). Since the PSK link was 7 dB above its margin of approximately 10^{-3} or 20 errors per second at the rate of 19.2 KB/SEC, and the time amplitude fluctuations did not approach this value, the errors were due to phase fluctuation of the receive carrier. This configuration constituted an indirect test of the phase disturbance of the received signal. The Data Acquisition Facility at Fort Detrick recorded rapid changes of C/kT on the EC Beacon (Figure #7). In addition, the HP-7100 BM chart recorder monitoring the elevation and servo voltages of the Fort Detrick antenna recorded the abrupt change in the elevation angle to the receive signal. It was concluded that the angle of arrival of the signal from the spacecraft had changed (Figure #8). During the many hours of recording, only at this one time did a change in error voltages appear.

CONCLUSIONS: The pattern and duration of the phenomena observed during this series of tests correlate closely with similar measurements made on the ATS-3 and LES-6 satellites (Figure #9). It can be concluded that scintillations do exist at SHF. Whatever the cause of the fluctuation, their effects on Communications between terminals located in disturbed and transitional geographic regions require further investigation. Until the nature of this phenomena is fully established, the reliability of world wide 24 hour-per-day satellite communications systems using high data rates or phase sensitive wideband PSK spread spectrum modulation will be carefully watched.

RECOMMENDATIONS: Further tests should be conducted at SATCOM Terminals located in the quiet, transitional, and disturbed

ABNORMAL BENDING
DUE TO TEMPORARY IONOSPHERIC DISTURBANCE
(CHANGE IN ELECTRON DENSITY)

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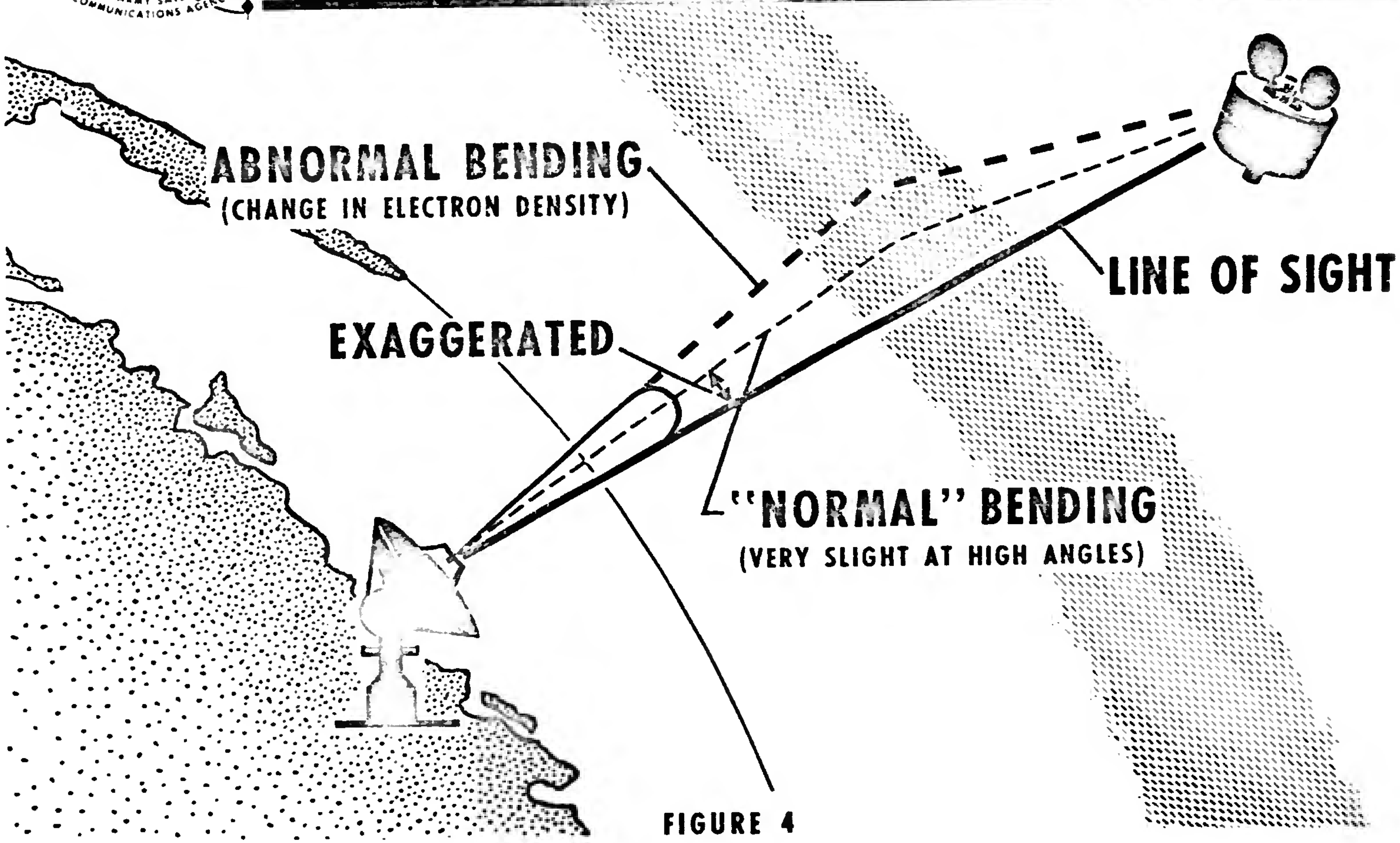

FIGURE 4

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SIMULTANEOUS SITE RECORDINGS

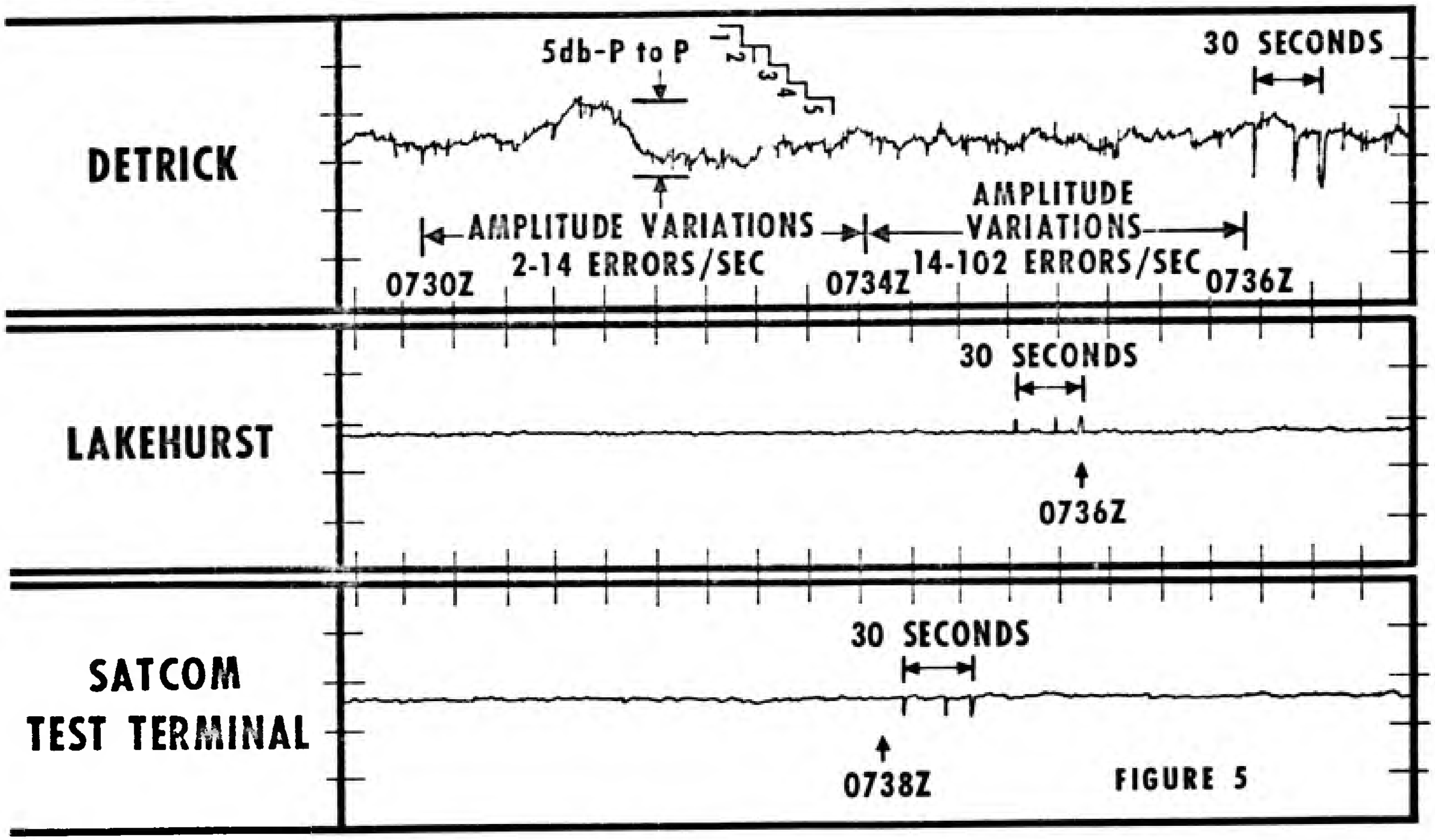

FIGURE 5

UNCLAS

SATCOM

ERROR RATES

TIME HRS/MIN/SEC	ERRORS/SEC
073250	2
073300	0
073310	10
073320	8
073330	8
073340	14
073350	60
073400	60
073410	56
073420	42
073430	64
073440	54
073450	40
073510	70
073550	102
073600	84
073700	86
073800	70

PERIOD OF GREATER AMPLITUDE VARIATIONS 2-14 ERRORS/SEC

PERIOD OF LESSER AMPLITUDE VARIATIONS 14-102 ERRORS/SEC

FIGURE 6

VARIATIONS IN C/KT - 1 SECOND INTERVALS
FORT DETRICK

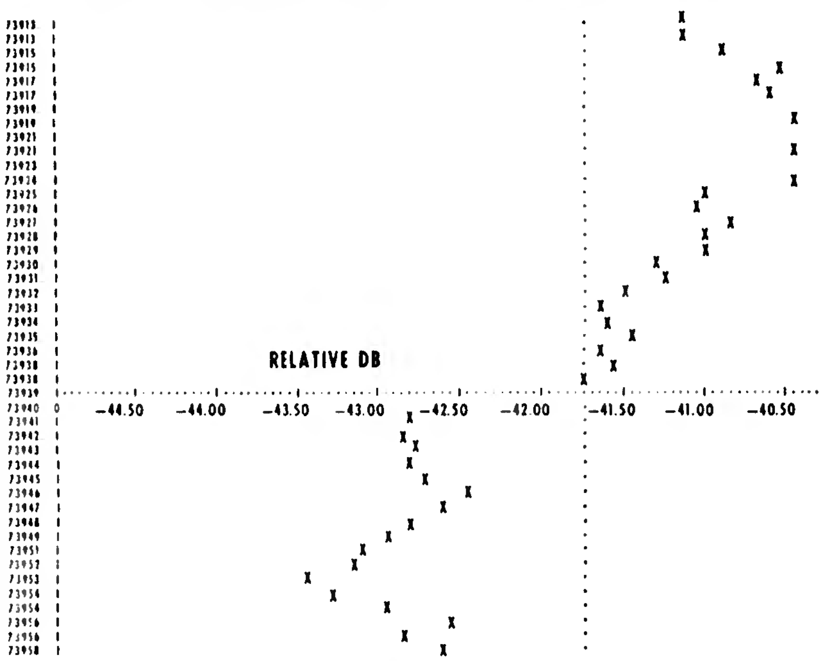

FIGURE 7

ANGLE-OF-ARRIVAL ERROR VOLTAGES-ELEVATION FORT DETRICK AN/MSC-60 – 10 DEC 1974

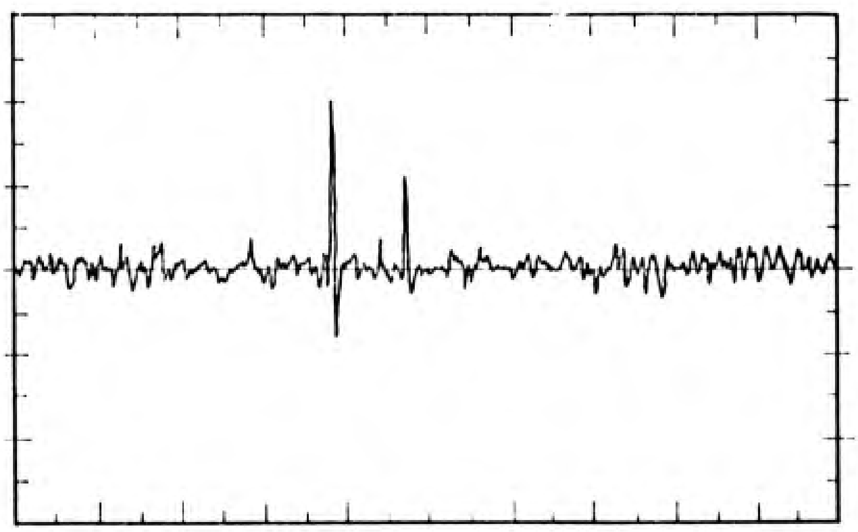

FIGURE 8

SCINTILLATION PATTERNS (UHF)

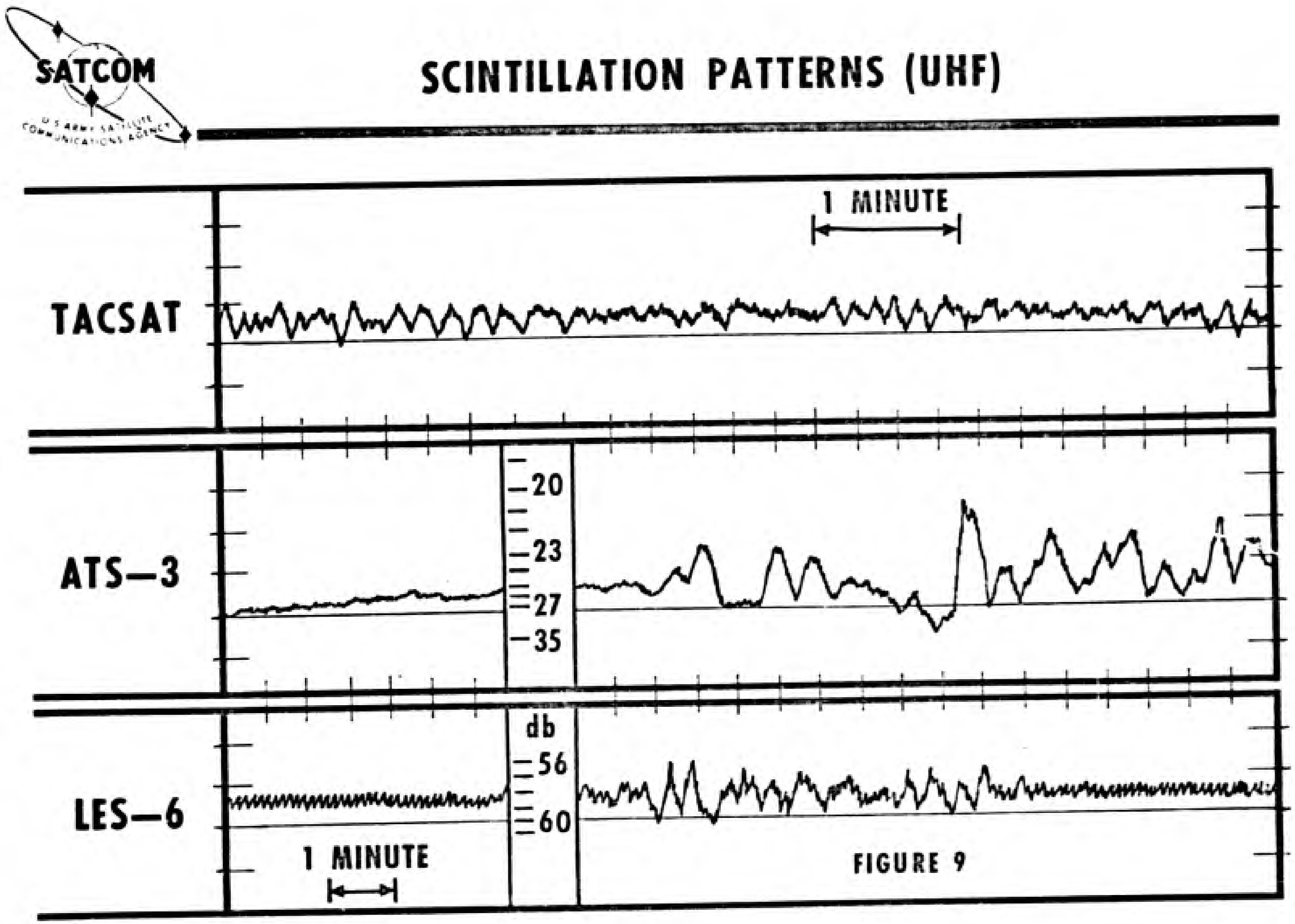

FIGURE 9

geographic regions to determine the impact and degradation of Satellite Communications using the high data rates as the modulation medium.

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